

Listing of Claims

Please amend the claims as follows. This Listing of Claims will replace all prior versions and listings of claims in this application:

Claims

1. – 30. (Canceled)

31. (New) A method for substantially completely decomposing undesirable organic chemical substance(s) in an aqueous solution and/or dispersion, said method comprising the ultraviolet laser treatment step of exposing an aqueous portion containing one or more undesirable chemical substance(s) to ultraviolet laser irradiation at a suitable ultraviolet wavelength and at a sufficient energy density for a sufficient period of time of about 15 minutes or less substantially to decompose the undesirable chemical substance(s) in the aqueous portion.

32. (New) A method according to claim 31 wherein the ultraviolet laser irradiation used for the ultraviolet laser treatment step consists substantially exclusively of ultraviolet laser irradiation having a wavelength of about 180 nm to 400 nm ($55,560\text{ cm}^{-1}$ to $25,000\text{ cm}^{-1}$) that delivers an energy density in the range of about 0.10 to 10 millijoules per square millimeter of ultraviolet laser beam cross-section to said aqueous portion.

33. (New) A method according to claim 31 wherein the ultraviolet laser irradiation consists substantially exclusively of ultraviolet laser irradiation having a wavelength of about 193 nm ($51,810\text{ cm}^{-1}$) or lower.

34. (New) A method according to claim 31 wherein the total period of time during which the aqueous portion is exposed to the ultraviolet laser irradiation to achieve substantially complete decomposition of at least one of the undesirable chemical substances is about 1 second to 10 minutes.

35. (New) A method according to claim 31 wherein the total period of time during which the aqueous portion is exposed to the ultraviolet laser irradiation to achieve substantially complete decomposition of at least one of the undesirable chemical substances is less than one second.

36. (New) A method according to claim 31 wherein 90% or more of at least one chemical substance originally present in the aqueous portion is decomposed during an ultraviolet laser irradiation period of less than 15 minutes.

37. (New) A method according to claim 31 wherein the aqueous portion, prior to the ultraviolet laser treatment step, contains one or more chemical substances selected from the group consisting of polychlorinated bi-phenyls, dioxins, 1-4 dioxane, pentachlorophenol, tri- and di-nitro toluene, chlorinated organic compounds, fluorinated organic compounds, and

mixtures thereof and, after said ultraviolet laser treatment step, the aqueous portion contains substantially none of these chemical substances.

38. (New) A method according to claim 31 wherein the aqueous portion before the ultraviolet laser treatment step contains at least a polyfluorinated organic compound having at least eight carbon atoms and, after said ultraviolet laser treatment step, the aqueous portion contains substantially none of such chemical substance(s).

39. (New) A method according to claim 31 wherein a catalyst is added to the aqueous portion before or during the ultraviolet laser irradiation step.

40. (New) A method according to claim 31 wherein said ultraviolet laser irradiation is delivered to the aqueous portion in pulses at a pulse rate ranging from about 1 to 50,000 pulses per second.

41. (New) A method according to claim 31 wherein said ultraviolet laser irradiation is delivered to the aqueous portion in pulses at a pulse rate ranging from about 10 to 1000 pulses per second.

42. (New) A method according to claim 31 wherein said ultraviolet laser irradiation is delivered to the aqueous portion in pulses at a pulse rate ranging from about 25 to 100 pulses per second.

43. (New) A method according to claim 31 further comprising the step of applying a combination of an ultraviolet laser pulse rate ranging from about 10 to 1000 pulses per second and an energy density ranging from about 0.10 to 10 millijoules per square millimeter of ultraviolet laser beam cross-section so as to deliver to the aqueous portion sufficient laser energy to effect substantially complete decomposition of said undesirable chemical substance(s) within a total treatment time of about 15 minutes or less.

44. (New) A method according to claim 31 further comprising the step of applying a combination of an ultraviolet laser wavelength or wavelengths within the range of about 180 nm to about 400 nm ($55,560\text{ cm}^{-1}$ to $25,000\text{ cm}^{-1}$), an ultraviolet laser pulse rate ranging from about 10 to 1000 pulses per second, and an energy density ranging from about 0.10 to 10 millijoules per square millimeter of ultraviolet laser beam cross-section so as to deliver to the aqueous portion sufficient laser energy at suitable wavelengths to effect substantially complete decomposition of said chemical substance(s) within a total treatment time of about 15 minutes or less.

45. (New) A method according to claim 31 further comprising a monitoring step of periodically or continuously monitoring the concentration of the undesirable chemical substances in the aqueous portion during the ultraviolet laser treatment step.

46. (New) A method according to claim 45 wherein said aqueous portion is treated with an ultraviolet laser light beam while flowing in a conduit having a longitudinal axis, said laser light beam being oriented substantially parallel to the longitudinal axis of

said conduit, wherein said monitoring step is performed continuously during the ultraviolet laser treatment step at two or more locations along the axis of said conduit.

47. (New) A method according to claim 45 wherein said monitoring step comprises the steps of passing a light beam: (a) through a first optically transparent wall portion of a container holding said aqueous portion during the ultraviolet laser treatment step, (b) through the aqueous portion being treated with ultraviolet laser radiation in said container, (c) out of said container through a second optically transparent wall portion of said container, and (d) into a spectrometer for monitoring the spectrophotometric signature of the aqueous portion during the ultraviolet laser treatment step.

48. (New) A method according to claim 31 wherein the aqueous portion is exposed to the ultraviolet laser irradiation in a batch, semi-batch, or continuous flow process.

49. (New) A method according to claim 31 wherein the treatment step of exposing the aqueous portion containing undesirable chemical substance(s) to ultraviolet laser irradiation is carried out without adding an oxidant to the aqueous portion.

50. (New) A method according to claim 31 wherein the treatment step reduces the concentration of the chemical substance(s) in the aqueous portion to a level that is consistent with environmental regulations for discharging a treated aqueous portion to the environment.

51. (New) A method according to claim 31 wherein the ultraviolet laser irradiation delivers at least ten times the energy of a conventional ultraviolet lamp light beam per square millimeter of ultraviolet laser beam cross-section to the aqueous portion.

52. (New) A method according to claim 31 wherein the ultraviolet laser irradiation consists of highly monochromatic ultraviolet laser light at one or several distinct monochromatic ultraviolet wavelengths.

53. (New) A method according to claim 52 further comprising the steps of determining the one or several monochromatic ultraviolet laser light wavelengths which are the most effective ultraviolet laser light wavelengths for decomposing the undesirable chemical substance(s) present in the aqueous portion, and delivering to the aqueous portion ultraviolet laser irradiation substantially consisting of only such most effective ultraviolet laser light wavelengths.

54. (New) A method according to claim 31 further comprising the steps of determining the one or several ultraviolet laser light wavelengths which are the most effective ultraviolet laser light wavelengths in decomposing the undesirable chemical substance(s) present in the aqueous portion based on the respective chemical atomic bonding energies of those undesirable chemical substance(s), and delivering to the aqueous portion ultraviolet laser irradiation substantially consisting of only such most effective ultraviolet laser light wavelengths.

55. (New) A method according to claim 31 further comprising the steps of: directing an ultraviolet laser beam from an ultraviolet laser device into a reaction vessel containing the aqueous portion through a substantially ultraviolet-transparent optical window portion so as to irradiate the contents of the reaction vessel; orienting a deuterium lamp toward the reaction vessel so as to direct light beams through the reaction vessel substantially at right angles to the ultraviolet laser beam; and, continuously monitoring the ultraviolet spectrophotometric signature of the contents of the reaction vessel using an ultraviolet spectrophotometric system to provide an indication of the chemical decomposition reactions occurring within the reaction vessel.

56. (New) A method according to claim 55 further comprising the step of turning off the laser and removing the treated aqueous portion when the rate of change of the spectrophotometric signature significantly slows or ceases and thereby indicates substantial completion of the chemical decomposition process.

57. (New) A method according to claim 56 wherein a water sample containing a known concentration of the undesirable chemical substances(s) of interest is placed in the reaction vessel and is treated by the ultraviolet laser treatment, the irradiated water sample is thereafter removed for further analysis, and the results of such analysis are used to ascertain the completeness of the chemical decomposition of the undesirable chemical substance(s).

58. (New) A method according to claim 57 wherein water samples with varying

known concentrations of the undesirable chemical substance(s) are irradiated with ultraviolet laser irradiation according to the method, and the results are compared for effectiveness in decomposing the substance(s).

59. (New) A method according to claim 31 further comprising the steps of: preparing test samples consisting of a distilled water blank and different aqueous perchlorate solutions containing from 5 ppm to 500 ppm of perchlorate in distilled water; setting aside one portion of each perchlorate solution as a reference portion; treating another portion of each perchlorate solution in a synthetic quartz reaction vessel by irradiating each sample with an excimer laser producing a monochromatic 193 nm ($51,810\text{ cm}^{-1}$) wavelength beam operating at an energy level of 100 millijoules per pulse at a frequency of 50 pulses per second, wherein the laser beam is directed along the long axis of the reaction vessel and completely covers an optical window section of the reaction vessel so as to substantially fill the reactor cavity with ultraviolet laser light and to deliver an ultraviolet laser light energy intensity of about 0.57 millijoules/square millimeter/pulse, based on the area of the optical window section, to each treated perchlorate portion thereby obtaining 95% or greater decomposition of the perchlorate in each treated perchlorate portion over a period of less than 15 minutes of irradiation.

60. (New) A method according to claim 59 further comprising the steps of: mounting a deuterium lamp and a spectrometer perpendicular to the long axis of the reaction vessel; directing light from the deuterium lamp through the reaction vessel and the contents of the reaction vessel and thereafter into the spectrometer; and measuring the ultraviolet

spectrum of the contents of the reaction vessel as a function of time while each sample is being exposed to the ultraviolet laser light.

61. (New) Apparatus for treating an aqueous solution and/or dispersion of undesirable inorganic chemical substance(s) so as to substantially completely decompose the undesirable chemical substance(s), said apparatus comprising in combination:

(a) a reaction vessel having an interior region to contain an aqueous portion having the undesirable chemical substance(s) during treatment;

(b) an ultraviolet laser device proximate to said reaction vessel capable of generating an ultraviolet laser beam at a wavelength or wavelength range of about 180 nm to 400 nm ($55,560\text{ cm}^{-1}$ to $25,000\text{ cm}^{-1}$); and,

(c) a laser beam window portion of said reaction vessel that is substantially transparent to ultraviolet laser radiation at wavelengths between about 180 nm to 400 nm ($55,560\text{ cm}^{-1}$ to $25,000\text{ cm}^{-1}$) and is oriented substantially orthogonally relative to the ultraviolet laser beam to pass ultraviolet laser radiation from said ultraviolet laser device into said interior region.

62. (New) Apparatus according to claim 61 further wherein the ultraviolet laser device is capable of producing ultraviolet laser light having at least ten times the energy of conventional ultraviolet lamp light per square millimeter of ultraviolet laser beam cross-section.

63. (New) Apparatus according to claim 61 further comprising an analytical system for continuously monitoring changes in the chemical composition of an aqueous portion in the reaction vessel during irradiation of the aqueous portion with ultraviolet laser radiation from the ultraviolet laser device.

64. (New) Apparatus according to claim 63 wherein said analytical system comprises an interlinked deuterium lamp device, a spectrometer, and a computer system.

65. (New) Apparatus according to claim 64 wherein said deuterium lamp device is oriented to deliver one or more beams of light through a first optically transparent wall portion of the reaction vessel and into the interior region, through the interior region of the reaction vessel including through the aqueous portion therein, out of the interior region through a second optically transparent wall portion of the reaction vessel, and thereafter into the spectrometer.

66. (New) Apparatus according to claim 61 wherein said reaction vessel comprises a quartz tube.

67. (New) Apparatus according to claim 61 wherein the area and shape of said laser beam window portion of said reaction vessel are substantially the same, respectively,

as the area and shape of a cross-section of the laser beam generated by the ultraviolet laser device.

68. (New) Apparatus according to claim 61 wherein said ultraviolet laser device is capable of generating a pulsed ultraviolet laser beam capable of delivering an energy density in the range of about 0.10 millijoules to 1 joule per square millimeter per pulse to an aqueous portion in the reaction vessel at a pulse rate of about 1 to 50,000 pulses per second.

69. (New) Apparatus according to claim 61 wherein said ultraviolet laser device generates a monochromatic laser beam at a wavelength of about 193 nm ($51,810 \text{ cm}^{-1}$) or lower.

70. (New) Apparatus according to claim 61 wherein said reaction vessel includes fluid inlet and fluid outlet ports such that said aqueous portion having undesirable chemical substances can be continuously flowed through the interior region of said reaction vessel.

71. (New) Apparatus according to claim 70 further comprising valves associated respectively with said fluid inlet and fluid outlet ports for alternately stopping or resuming fluid flow.

72. (New) Apparatus according to claim 70 wherein said fluid inlet and fluid outlet ports are arranged such that the aqueous portion is flowed through said reaction vessel in a direction of flow opposite to the direction of the ultraviolet laser beam through the vessel.